EFFECT OF HOUSEHOLD POVERTY ON WOODFUEL CONSUMPTION IN SUB-SAHARAN AFRICAN COUNTRIES: EVIDENCE FROM SYSTEM GMM MODEL

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ABSTRACT
This study aims to investigate the effect of household poverty on woodfuel consumption in Sub-Saharan African countries by using a panel data set of 43 countries spanning from 2011 to 2019. Generalized Method of Moment (GMM) was employed to analyze the data. The finding of the study reveals a strong positive association between household poverty and woodfuel consumption, with a 1% increase in household poverty increasing woodfuel consumption by 65.1%. The study further reveals that clean fuel and technology, dependency ratio, and female labor participation were significant determinants of woodfuel consumption in Sub-Saharan African countries. These findings have significant implications for the health and economic well-being of the region's population. Sub-Saharan African governments, non-governmental organizations, donor agencies, and foundations are urged to make clean cooking energy, such as electricity, gas, and solar, more readily available and affordable to households, easing the transition from wood fuel to cleaner fuels.
Keywords: Wood fuel, Household, Poverty, Sub-Saharan Africa, GMM.
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1. INTRODUCTION
Energy access is crucial for poverty reduction since it allows people to access modern energy services, improves their health and well-being, and boosts economic production (IAEA 2025; World Bank, 2022). Many households in developing countries lack access to modern energy services; thus, they rely on traditional sources such as woodfuel (FAO, 2022). Wood fuel consumption is widespread in developing countries, particularly in rural areas where modern energy services are scarce, with over 2.7 billion people worldwide relying on it for cooking, heating, and lighting (FAO, 2023). In Sub-Saharan Africa, wood fuel is the primary energy source for cooking, heating, and lighting (IEA, 2025; World Bank, 2022). The region is home to almost 1.2 billion people, many of whom live in rural areas with limited access to modern energy services (UNDP, 2023). Sub-Saharan Africa is the world's largest consumer of woodfuel, accounting for more than 80% of total cooking energy consumption (IEA, 2025). In some Sub-Saharan African countries, such as Nigeria, 72.2% of households used woodfuel for their cooking (Adeyemi, 2025). More than 2.2 million Ghanaian households also use wood fuel for cooking, heating, and lighting (Ghana Statistical Service, 2020).

Wood fuel consumption has numerous environmental and health consequences, including deforestation, forest degradation, biodiversity loss, and ecosystem disruption, as well as contributing to climate change by releasing stored carbon into the atmosphere (Food and Agricultural Organization, 2022). It also reduces the carbon-sink potential of forests and causes soil erosion, particularly in areas with steep slopes or unstable soil. Burning wood for cooking and heating emits pollutants such as particulate matter, carbon monoxide, and volatile organic compounds, which can lead to respiratory problems and other health issues (World Health Organization, 2022). Woodfuel consumption is a major source of mortality in Sub-Saharan African countries such as Nigeria, Ghana, and South Africa (with estimated rates of 150, 120, and 90 per 1,000 live births, respectively).

Poverty could have a significant effect on woodfuel consumption in developing countries, particularly in Sub-Saharan Africa, where over 67% of the world's extreme poverty is concentrated (World Bank, 2024). The high level-poverty in the region may hinder households' ability to invest in energy-efficient devices like electricity, LPG, solar, biogas, and new cookstoves, which are essential for addressing the global issue of extreme poverty. Lack of access to clean energy is a major issue in Sub-Saharan Africa, where more than 940 million people cannot afford to use clean cooking energy for cooking, heating, and lighting and instead rely on conventional cooking fuels such as woodfuel (UN, 2025). This could have serious implications such as deforestation, habitat loss, indoor air pollution, inequality, and decreased economic activity. The situation is projected to deteriorate with an estimated more than 840 million people in Sub-Saharan Africa having lack of access to clean cooking fuel by 2030, and about 1.1 billion by 2050 (IEA, 2025). This would jeopardize the United Nations' seventh Sustainable Development Goal (SDG), which states that everyone should have access to affordable clean cooking energy and technology by 2030. This study thus became imperative to determine the empirical effects of household poverty on woodfuel consumption in sub-Saharan Africa to stimulate and expedite policy action towards achieving the SDGs' goal on access to clean energy by 2030.

The remainder of this paper is organized as follows: Section two contains the theoretical and empirical literature. Section three contains the methodology. Section four presents and discusses the results, and lastly, section five contains the summary, conclusion, and policy recommendations.

2. LITERATURE REVIEW

2.1 Theoretical Literature

This subsection explores theoretical literature related to the study's objective, including energy ladder theory, energy staircase theory, and energy poverty theory, which provide a framework for analyzing household energy consumption and factors influencing cooking energy decisions.

Energy Ladder Theory

Gerald Leach, known for his work on energy ladder theory, proposed a framework in 1976 for understanding the transition from biomass fuel to modern energy sources (Leach, 1976). The theory demonstrates a hierarchical relationship between a household's income and cooking fuel type, illustrating how energy consumption and demand patterns change as a household's economic situation changes. Leach and Mearns (1988) expanded the energy ladder model to include income, education, and energy source access. Kammen (1995) further developed the theory, emphasizing the need to comprehend the social, economic, and environmental context

of energy transition. Masera et al (2006) critique the energy ladder theory, arguing it simplifies complex factors influencing household energy choices, proposing an alternative framework called the energy staircase theory.

Energy Staircase Theory

Masera et al (2006) developed the energy staircase theory as an alternate framework to the energy ladder theory. This approach recognizes that households may adopt numerous energy sources at the same time, rather than moving up the energy ladder in a linear fashion. According to the hypothesis, households can use many sources of energy at the same time, including biomass fuel, charcoal, kerosene, and electricity. The theory also assumed nonlinear progression, recognizing that families may not climb up the energy ladder in a linear form but rather adopt numerous energy sources in a nonlinear manner. Giri and Sharma (2014) disputed this idea, claiming that it is based on household surveys, which may be biased and limited.

Energy Poverty Theory

The theory of energy poverty originated in the 1970s but received substantial attention in the 1990s and 2000s. Boadman's (1991) work on fuel poverty in the United Kingdom highlights the difficulty of households unable to afford appropriate heating. Dubois and Meier (2004) have expanded the energy poverty hypothesis by addressing issues of access, affordability, and energy efficiency. Sovacool (2012) questioned the theory, arguing that it oversimplifies the complex relationship between energy and poverty. The author argues that energy poverty is often defined within a narrow framework that overlooks social, cultural, and environmental factors. Furthermore, Bazillian and Modjtahedi (2019) argues that energy poverty theory focuses on symptoms rather than core causes like poverty, inequality, and lack of access to energy infrastructure.

Based on the theories discussed thus far, researchers chose the energy ladder theory to serve as the theoretical foundation for this investigation. This is because, according to energy ladder theory, low-income households rely mainly on wood fuel because of its affordability. The theory also emphasizes that poverty is a key obstacle to accessing modern energy services, resulting in continuous reliance on traditional wood fuel for cooking, heating, and other domestic activities.

2.2 Empirical Literature

Existing empirical literature shows that there was accumulating evidence linking poverty with cooking fuel. However, some of the empirical studies that attempted to investigate the association between polluting fuel and household poverty used either descriptive surveys or cross-sectional studies on individual countries, villages, or districts with limited coverage (Longe, 2021; Oladimeji et al., 2015; Darisgupta et al., 2006; Khundi et al., 2011; Falak et al., 2014; Ogwumuke & Ozughalu, 2014; Techato et al., 2018; Isah & Ahman, 2020; Hou et al., 2018; Shahid et al., 2022; Ogbiede-Osaretin, 2021; Akeh, 2025; Mperejekumana et al, 2021; Adeeyu, et al., 2022). Because of the small sample sizes used in these studies, broad conclusions cannot be drawn, necessitating a multi-country investigation of the relationship between SSA household poverty and woodfuel use.

Similarly, some of the existing studies that investigate the effect of poverty on woodfuel consumption were based on individual countries, towns, or districts (Bologun et al, 2020; Netshipise, & Semenya, 2022; Waris & Antahal, 2014; Dermurger & Founier, 2011; Dermurger & Founier, 2010). None of these studies investigate the effect of poverty on woodfuel consumption in sub-Saharan African countries despite the fact that the region emerged as the highest region with extreme poverty rates. This therefore misses out on an important fact about the role of household poverty in explaining woodfuel consumption in sub-Saharan African countries. This study seeks to address this gap by looking into the effect of household poverty on woodfuel consumption in Sub-Saharan African countries using the system Generalized Method of Moment (GMM).

3. METHODOLOGY

3.1 Theoretical Framework

The Leach energy ladder model, which was developed in 1976, serves as the theoretical foundation for this research. The model suggests that poor households primarily use traditional biomass fuel due to its affordability, and that poverty is a significant barrier to accessing modern energy services, leading to continuous reliance on traditional fuel for domestic activities. The model is specify as:

B= f (P) …… (1)

Where B is the traditional biomass fuel and a function of P, which stands for household poverty. Leach and Mearns (1988) expanded the energy ladder model to include income and education as other factors that influence households' energy choice. The relationship between these variables and health outcomes is expresse…….. (2)

Where B is the dependent variable in the model which stand for traditional biomass fuel and P is the independent variable which stands for household poverty. Y and ED represents household income and level of education of the household to serves as other controlled variable in the model.

3.2. Empirical Model

Following the theoretical framework of Leach (1976), Leach and Mearns (1988), our model is specify as follows:

$WFC\ f(POV, CFT, DR, EDU, FLP)$…….....……..(3)

WFC denotes woodfuel consumption, and POV stands for household poverty. Whereas CFT, DR, EDU, and FLP stand for clean fuel and technology, dependency ratio, education of the household, and female labor participation, respectively, they serve as control variables. These variables were added to the model to avoid the issue of functional specification of error and to further advance knowledge on how household poverty influences woodfuel consumption. Furthermore, by incorporating the intercept and disturbance variables into model 4, we can derive the following econometric model:

$WFC = \alpha_0 + \alpha_1 POV + \alpha_2 CFT + \alpha_3 DR + \alpha_4 EDU + \alpha_5 FLP + \eta$ ……*(4)*

In a similar spirit, the following fixed panel data model can be generated from the aforementioned econometric model:

$$WFC_{it} = \alpha_0 + \alpha_1 POV_{it} + \alpha_2 CFT_{it} + \alpha_3 DR_{it} + \alpha_4 EDU_{it} + \alpha_5 FLP_{it} + \eta_t + \lambda_i + \Pi_{it} \ldots\ldots\ldots\ldots (5)$$

Where i represents the number of Sub-Saharan African countries included in this study, and t represents time expressed in years. η_t represents the time-invariant country-specific effect that accounts for variations among the panel countries, while λ_i is the country-specific time variation effect. While Π_{it} is a time-variant error term representing all other factors that might have an impact on the woodfuel consumption in SSA but are not taken into account by the model. The Generalized Method of Moment (GMM) model developed by Arellano and Bond (1991) and Arellano and Bover (1995) was utilized in the study to address the drawbacks of the fixed panel OLS model in dealing with heterogeneity issues such as time-invariant inequalities in the sample countries. Because the model is dynamic, it can help to solve the problem with fixed panel models. As a result, the GMM model specifications are as follows:

$$WFC_{it} = \alpha_0 + \ell WFC_{it-1} + \alpha_0 + \alpha_1 POV_{it} + \alpha_2 CFT_{it} + \alpha_3 DR_{it} + \alpha_4 EDU_{it} + \alpha_5 FLP_{it} + \eta_t + \lambda_i + \eta_{it} \quad \ldots\ldots (6)$$

Woodfuel consumption in Sub-Saharan African countries is the dependent variable for the model and is denoted by WFC_{it}. On the other hand, WFC_{it-1} is the lagged dependent variable that takes care of the dynamic properties of the panel GMM model; α_1, α_2, α_3, α_4, α_5, α_6, α_7, and α_8 represent the coefficients of all the log form independent variables in the model equation.

The study predicts that the coefficients for household poverty are positively related to woodfuel consumption. The vector of the independent variable (CFT, DR, EDU, and FLP) serves as elasticity in measuring the degree of variation or changes in woodfuel consumption in Sub-Saharan African countries as a result of variation in the independent variables.

3.3 Variable Descriptive and Expected Sign

To measure the effect of household poverty on woodfuel consumption, wood fuel consumption (WFC) was employed as a dependent variable. It is measured in cubic meters (m^3) per thousand. It is used to quantify the volume of wood fuel consumed. Household poverty (POV) is used as an independent variable, which is defined as the international poverty line set at \$2.15 per person per day in 2017 purchasing power parity (PPP) terms. It is expressed as a percentage of the population living below \$2.15 threshold. It is expected to be positively associated with woodfuel consumption.

Clean fuel and technology (CFT), expressed as the proportion of the population having access to clean fuel such as electricity or cooking gas, is expected to show a negative sign in relation to woodfuel consumption. The dependency ratio (DR) expressed as a percentage of dependents aged 0-14 years is expected to have a positive coefficient in relation to woodfuel consumption. Education of the household (EDU), which is measured by the number of years spent acquiring secondary education, is expected to show a negative sign in relation to woodfuel consumption. The female labor participation rate (FLP) is the percentage of women aged 15-64 who are employed and is expected to have a negative sign in relation to woodfuel consumption.

3.4 Data Source

Data for household poverty were sourced from the World Bank PovcalNet database. While the data for household woodfuel consumption were sourced from the United Nations Statistics Division 2021. Data for clean fuel and technology, dependency ratio, education, and female labor participation were sourced from the World Development Indicator 2022. The study covered 43 Sub-Saharan African countries from the year 2011 to 2019. These countries were chosen based on data availability and a nine-year period that fell within the parameters of an acceptable panel data rule.

4. RESULTS AND DISCUSSION OF FINDINGS

Before estimating the main model, descriptive statistics such as mean, standard deviation, minimum, and maximum values were computed. Table 1 presents summary statistics for the variables used to analyze the effect of household poverty on woodfuel consumption in Saharan African countries:

Table 1: Descriptive statistics on the effect of Household Poverty on Woodfuel Consumption in Saharan African countries

VARIABLE	MEAN	STD. DEV.	MIN	MAX	OBS
WFC_{it}	13771.45	28293.9	3.16	173313	396
POV_{it}	33.59972	20.47519	0.08	81.48	396
CFT_{it}	43.84796	25.4685	4.1	100	396
DR_{it}	5.834182	1.718656	3.089473	15.84723	396
EDU_{it}	8.025253	1.875726	5	12	396
FLP_{it}	43.60033	20.37719	4.47	88.19	396

Source: Authors' computation with data using Stata version 16

Data in Table 1 show that woodfuel consumption has an overall annual mean of 13,771.45 m^3. This implies that on average, households in Sub-Saharan African countries consumed about 13,771.45 m^3 of woodfuel for the period 2011-2019. The overall annual household poverty rate is 33.59972, implying that 34% of the population in Sub-Saharan African countries lives in extreme poverty on average during the study period. The proportion of the population who had access to clean fuel and technology constitutes 43.84796. This implies that on average, about 44% of households in Sub-Saharan Africa within the study period had access to clean fuel and technology for the 2011-2019 period. The dependency ratio has an overall annual mean of 5.834182% on average. This implies that the average number of dependents aged 0-14 are dependent. Education of the household has a ratio of 8.025253 years on average during the period of the study. This means that the number of years spent by the households during the period of the study is 8%. The female labor participation rate is 43.60033% on an annual basis. This implies that the average number of women who are gainfully employed has an average of 44%. Table 1 further shows that the variable with the highest standard deviation is CFT with 25.4685, and the lowest is DR with 1.718656. Each of the variables has 396 observations. This demonstrates that there are notable differences both within and between nations. This supports the application of the panel GMM estimation approach. Correlation matrix was also conducted to determine the intensity of the collinearity among the variables. Table 2 shows that there is no perfect correlation among the variables.

Table 2: Correlation Matrix on the effect of Household Poverty on Woodfuel Consumption in Saharan African countries

	WFC	POV	CFT	DR	EDU	FLP
WFC	1					
POV	0.1037	1				
CFT	-0.0758	-0.7189	1			
DR	-0.1122	-0.5051	0.6027	1		
EDU	-0.0374	-0.3275	0.33	0.1936	1	
FLP	-0.0868	-0.6984	0.7715	0.534	0.2547	1

Source: Authors' computation with data using Stata version 16

Table 2 shows that the variables included in the model were not highly correlated because their degree of correlation was less than 0.80. The highest correlation (0.7) is between POV and CFT, while the lowest is between WFC and EDU (-0.0374). According to the rule of thumb, the degree of correlation should not be greater than 0.80. (Sulaiman et al., 2017; Waziri et al.,

2018). This shows that the degree of correlation remains constant throughout and that our estimate is completely immune to multicollinearity.

The estimated model results using system GMM with woodfuel consumption as the dependent variable are shown in Table 3. The specification tests validated the suitability of the GMM estimators. The Hansen J-test, for example, does not reject over-identifying restrictions as 0.338 > 0.005. This suggests the identifying restrictions are valid and the GMM model is correctly specified and consistent with the data. Similarly, the Diff-in-Hansen test rejects the null hypothesis (0.705 > 0.005). This suggests that the instruments used in the model are correctly specified and consistent with the data. The number of groups (44) is greater than the number of instruments (41) in the model. The lagged dependent variable is both positive and significant, indicating the dynamic nature of the model. These tests supported the use of system GMM estimation.

Table 3: GMM estimation on the effect of Household Poverty on Woodfuel Consumption in Saharan African countries

Variables	System GMM
	Coefficient
$lnWFC_{it}$	.980 (.017)***
$lnPOV_{it}$	65.157(23.298)***
$lnCFT_{it}$	-48.426(22.928)***
$lnDR_{it}$	142.749(69.661)***
$lnFLP_{it}$	45.080(23.512)**
AR (2)	0.338
Hansen test of ORR	0.705
Difference-in-Hansen	0.355
Number of observations	352
Number of groups	44
Number of instruments	41

Note that values in parenthesis represent the standard error, while ***, ** and * represent significant level at 1%, 5% and 10% respectively

Source: Authors' computation with data using Stata version 16

The estimated results in Table 3 confirmed our earlier prediction that woodfuel consumption will raise the poverty rate in Sub-Saharan Africa. The estimated poverty coefficient in system GMM shows that a 1% increase in household poverty results in a 65% increase in woodfuel consumption. This indicates that woodfuel consumption in Sub-Saharan Africa is strongly linked to rising poverty. The magnitude of poverty is far too great. This could be due to the region's high rate of extreme poverty. This strong association suggests that as households face greater economic hardships, they increasingly rely on woodfuel as a primary energy source. Consequently, this reliance may perpetuate a cycle of poverty, making it difficult for families to escape their economic challenges. The findings of this study are consistent with those of Bologun (2020), who reveals that household poverty is the main driver that promote woodfuel consumption among households in Kaduna metropolis, Nigeria. Netshipise, and Semenya (2022) revealed a similar finding on the association between poverty and woodfuel consumption, stating that household poverty increases woodfuel consumption among Thulamela Local Municipality, South Africa. The findings of this study is also in support the findings of Waris and Antahal (2014), who found a positive association between household poverty and woodfuel consumption in rural India. Their study reveals that household poverty promotes the usage of wood fuel for cooking. The findings of this study are also consistent

with those of Dermurger and Founier (2011), who discovered a positive and significant association between household poverty and woodfuel consumption in rural China, meaning that an increase in poverty increases the rate of woodfuel consumption.

The coefficients of control variables used in the system GMM model, such as access to clean fuel and technology, dependency ratio, and female labor participation, have the expected signs. The elasticity of access to clean fuel and technology (-48.426) indicated that a 1% increase in access to clean fuel and technology will reduce woodfuel consumption by 48%. This is consistent with the findings of Ogwumike and Ozughalu (2014), who discovered that using clean fuels such as electricity and gas in cooking reduces the use of polluting fuels like wood. Similarly, the coefficient of the dependency ratio corresponds to the expectation of the study and is consistent with the theory. Its elasticity indicates that a 1% increase in the dependency ratio increases woodfuel consumption by approximately 143%. Female labor participation also reveals a positive association with woodfuel consumption. Its elasticity indicates that a 5% increase in female labor participation will correspondingly increase woodfuel consumption by 45%. This is contrary to theoretical expectations. This finding may not be unconnected with the socio-economic context in which female labor participation occurs in many Sub-Saharan African countries. In this region, women often play a central role in household energy management, including the collection and utilization of woodfuel. Increased female labor participation may lead to higher household incomes, which could, counterintuitively, result in greater woodfuel consumption if modern energy services remain unaffordable or inaccessible. Additionally, traditional gender roles and responsibilities within households may persist despite increased economic participation by women, thus sustaining or even increasing the reliance on woodfuel for domestic energy needs. This underscores the complexity of the relationship between female labor participation and woodfuel consumption and highlights the necessity of addressing underlying factors such as access to affordable and modern energy services, gender dynamics, and socio-economic inequalities.

5. CONCLUSION AND POLICY RECOMMENDATIONS

This study showed a strong and positive association between household poverty and woodfuel consumption. This implies that increasing poverty leads to increased woodfuel consumption. The study concludes that poverty is a significant driver of woodfuel consumption, with households living in poverty relying heavily on woodfuel for cooking, heating, and lighting. Therefore, addressing household poverty and promoting alternative energy sources is crucial for sustainable development. The study recommends Sub-Saharan African governments to incorporate clean energy access into poverty reduction strategies, supporting initiatives like off-grid energy and energy-efficient technologies. Sub-Saharan African governments, Non-governmental organizations, donor agencies and foundations are recommended to make clean cooking energy, such as electricity, gas, and solar, available and affordable to households, facilitating the transition from wood fuel to cleaner fuel. However, this requires significant financial investments and measures. To achieve this, the study suggests a result-based financing project and broad participation from both public and private sectors. This can be done by forming a coalition of governments, local and international investors, international donor agencies, and foundations, to raise funds for clean cooking fuel in the studied countries. Sub-Saharan African governments should improve the empowerment of poor households by enabling them to afford clean fuels, technologies, and end-use appliances at market prices. This can be achieved through poverty alleviation programs, cash transfers, microcredit loans, tax holidays, and entrepreneurial opportunities.

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